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Hard Diffraction at DØ

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Preliminary results from the DØ experiment on dijet production with forward rapidity gaps in $\overline{p}p$ collisions are presented at center-of-mass $\sqrt{s} = 1800$ GeV and 630 GeV. The number of events with rapidity gaps at both center-of-mass energies is significantly greater than the expectation from multiplicity fluctuations and is consistent with a hard single diffractive process. We also observe an excess of events which contain jets and two rapidity gaps, a topology which is consistent with hard double pomeron exchange.

1 Introduction

Since the paper of Ingelman and Schlein [1] first proposed that the observation of jets would provide insight into the nature of the pomeron[a], the study of hard diffractive processes has expanded dramatically. The availability of high energy hadron beams at CERN, HERA and Fermilab have allowed studies of diffractive jet production [2,3,4], deep inelastic scattering in large rapidity gap events [5], and rapidity gaps between high transverse energy jets [6,8,7,9]. In this note we present a preliminary measurement of hard single diffraction (HSD) and a preliminary observation of hard double pomeron exchange (HDPE) using the DØ detector at Fermilab for center-of-mass energies $\sqrt{s} = 1800$ GeV and 630 GeV.

2 Hard Single Diffraction

Hard diffraction is a subset of the process $p + \overline{p} \rightarrow jet + jet + X$ which is attributable to pomeron exchange. Since the pomeron is a color-singlet, there is no color line between the outgoing beam particle and the jets produced in the scattering, so particle production in the pseudorapidity[b] region between the beam and the jets is suppressed. The lack of particles in a given pseudorapidity interval is the rapidity gap. The difference between HSD and HDPE is the

[a] The pomeron is described as a color singlet with the quantum numbers of the vacuum.
[b] pseudorapidity is defined as $\eta = -ln[tan(\frac{\theta}{2})]$, where θ is the polar angle defined relative to the proton beam direction.

presence of one forward rapidity gap in the case of HSD and two forward gaps in the case of HDPE.

We used POMPYT [10] to study the expected characteristics of proton-pomeron collisions in HSD and found that the particle multiplicity distribution in the forward rapidity region is peaked at zero, but with a tail that extends to larger multiplicities which depends on the choice of the pomeron model. To reduce the model dependence we accept events with small but non-zero multiplicities as gap events. PYTHIA [11] was used to study the characteristics of non-diffractive dijet events with the same jet requirements and we found that the multiplicity distribution is well described by a negative binomial distribution (NB). This multiplicity distribution has a large mean and very few events near the zero multiplicity bin, so the multiplicity distribution is a good tool for distinguishing diffractive and non-diffractive events.

3 Data Analysis

Descriptions of the DØ detector can be found elsewhere [12]. Since the detector can not directly measure the number of particles, we use the forward calorimeters to identify HSD candidates by studying the multiplicity of hit towers: the electromagnetic calorimeter in the range $2.0 < |\eta| < 4.1$ and the hadronic calorimeter in the range $3.2 < |\eta| < 5.2$. A tower is defined as hit for the deposition of more than 125 MeV of energy in an electromagnetic calorimeter tower or 500 MeV of energy in a hadronic calorimeter tower. Detector simulations show that the multiplicity distributions of hit towers preserve a clear difference between diffractive and non-diffractive events.

The data were collected at two different center-of-mass energies ($\sqrt{s} =$ 1800 GeV and 630 GeV) using an inclusive trigger requiring at least one jet above 15 GeV in E_T or a forward trigger requiring at least two jets above 12 GeV in the regions $|\eta| > 1.6$. Since the pomeron carries only up to 5% of the incident proton momentum, the jet system is expected to be boosted, so a forward trigger will enhance the sample of diffractive events. Offline, the trigger requirements are reinforced, events with multiple $\bar{p}p$ interactions are removed and standard quality cuts [13] are applied. Jets are reconstructed using the cone algorithm with radius $R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.7$.

We use three different definitions of the rapidity gap. The near gap, which is our "standard" definition, extends from $2.0 < |\eta| < 4.1$. The long gap spans the range from $2.0 < |\eta| < 5.2$ which restricts the possibility of an undetected excited proton. The far gap region is from $3.0 < |\eta| < 5.2$, which reduces the possibility of an excited diffractive state as in the long gap, and in addition improves the diffractive mass acceptance of the dijet system.

The number of hit towers (n_{CAL}) distribution for the forward trigger is shown in fig. 1. The distributions are shown for the three gap definitions and the two center-of-mass energies. The leading edge of the data (excluding the first few bins) is fit with a NB distribution. The fraction of rapidity gap events is defined as the number of gap events in excess of those predicted by the fit divided by the total number of events.

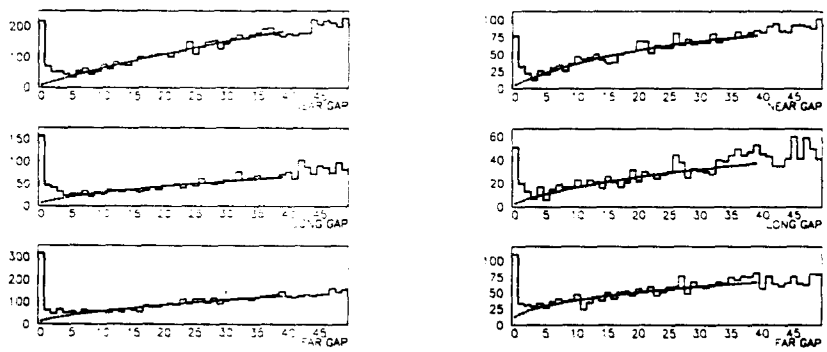


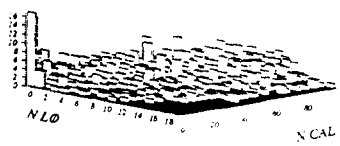
Figure 1: The multiplicity of hit towers for different gap definitions and center-of-mass energies. The lines are NB fits to the leading edge of the multiplicity distributions extrapolated to the zero multiplicity bin for the 1800 GeV (a) and 630 GeV (b). Table1 shows the measured gap fractions.

Table 1: Measured 1800 GeV and 630 GeV gap fractions in the short gap, long gap, and far gap regions. The error is statistical and the systematic fit error added in quadrature.

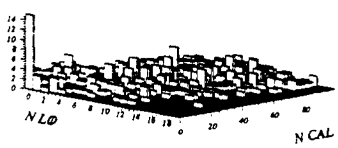
GAP DEFINITION	1800 GAP FRACTION	630 GAP FRACTION
Near ($2.0 < \|\eta\| < 4.1$)	0.76 ± 0.08 %	1.11 ± 0.23 %
Long ($2.0 < \|\eta\| < 5.2$)	0.57 ± 0.09 %	0.76 ± 0.15 %
Far ($3.0 < \|\eta\| < 5.2$)	1.04 ± 0.11 %	1.40 ± 0.39 %

4 Hard Double Pomeron Exchange

The HDPE data form a subset of the data used for the inclusive HSD analysis. A special trigger was implemented which, in addition to the jet requirements of the inclusive HSD trigger required a forward gap tagged by the LevelØ detector. For the subset of HSD events with two good jets in the central region and a forward rapidity gap, we examine the multiplicity of hit towers and the number of hits in the LevelØ detector on the opposite side. Such a plot is shown in fig 2. This shows a clear excess of events with 2 forward gaps and two central jets.



a) Multiplicity at 1800 GeV



b) Multiplicity at 630 GeV

Figure 2: Multiplicity distribution of calorimeter towers and LevelØ hits opposite a tagged rapidity gap is plotted for 1800 GeV (a) and 630 GeV (b)

5 Conclusions

We have observed a class of events with forward rapidity gaps and high E_T jets in the DØ detector in $\bar{p}p$ collisions at center-of-mass energies of 1800 GeV and 630 GeV. Events with a single forward rapidity gap are consistent with hard single diffractive jet production. The fraction of events with a forward gap is observed to be approximately the same at $\sqrt{s} = 1800$ GeV and at $\sqrt{s} = 630$ GeV. We also observe a class of events with forward rapidity gaps on both sides of two central jets, consistent with the expectations for the hard double pomeron exchange process.

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